Architectures for High-Performance Ceramic Composites Being Improved

A major thrust of the Ultra-Efficient Engine Technology (UEET) Program at the NASA Glenn Research Center is to develop advanced hot-section engine components using SiC/SiC ceramic matrix composites (CMC's) with thermostructural capability to 2400 °F (1315 °C). In previous studies, UEET determined that the higher the ultimate tensile strength (UTS) of the as-fabricated CMC, the greater its structural performance at 2400 °F (ref. 1). Thus efforts have been ongoing within UEET to understand and develop fiber architecture approaches that can improve the UTS of SiC/SiC CMC's.

Under UEET, SiC/SiC test panels and demonstration engine components are currently produced by the multi-ply layup of two-dimensional fabric pieces. The fabric is typically formed of multifilament tows containing high-performance Sylramic (Dow Corning) SiC fiber that is woven into two-dimensional five-harness satin fabric with 20 ends per inch in the 0° and 90° directions. In some cases, fabric pieces containing woven Sylramic fiber tows are thermally treated at NASA to form Sylramic-iBN fibers that contain a very thin in-situ-grown boron nitride layer on their surfaces (ref. 2). The final SiC/SiC panels and components are fabricated at the CMC vendor by compressing the fabric pieces in tools and then depositing a thin BN interphase coating on the fibers by chemical vapor deposition. The last step at the vendor is to infiltrate the BN-coated fiber architecture with SiC and silicon matrix constituents to form a dense product.

Because the as-produced Sylramic fiber tows are sized with a thin polymer coating to facilitate handling and weaving, the individual fibers within the tows and fabric are in close contact with each other. This contact is further increased during fabric compression. One important recent finding is that increasing Sylramic fiber tow width in a fabric increases the UTS of the final SiC/SiC CMC. This effect is presumably related to minimizing fiber/fiber contact, which can be detrimental to CMC strength because of the boron-rich chemistry and roughness of the Sylramic fiber surface (refs. 2 and 3). Tows can be spread by mechanically agitating the Sylramic fabric prior to CMC fabrication or by simply thermally treating the Sylramic fabric as in the formation of the Sylramic-iBN fibers. However, CMC's with the treated Sylramic-iBN fabric are even stronger than CMC's with mechanically spread Sylramic tows. The extra strength capability is presumably related to the in situ BN on the fiber surface, which adds compliance to the fiber surfaces and is more resistant to oxygen impurities introduced during the chemical vapor deposition BN process (refs. 2 and 3).

As shown in the table, another important finding is that the use of fabric with tows having less than the standard of 20 ends per inch provides advantages in terms of reduced ply height and increased ply and CMC strength. The reduced ply height provides more control of part thickness by allowing more plies for a given thickness and by reducing interlaminar residual stresses between plies. The increased ply strength is presumably related to a reduced number of interlaced 90° tows, which, in turn, reduces the crimp angle on the high-modulus fibers in the 0° tows. Also, as shown in the table, although fabric with fewer ends per inch reduced the maximum fiber fraction in an eight-ply CMC panel; CMC UTS actually increased because of increased ply strength. Thus, using fabric with fewer ends per inch has several advantages, including providing a significantly higher strength per fiber fraction in the CMC (last column in the table). Consequently, ongoing UEET efforts will attempt to use architectural approaches for components that minimize fiber-fiber contacts and fiber bending within the final composite microstructure.

EFFECTS OF FABRIC ENDS PER INCH ON CMC PROPERTIES

Fabric ends per inch	**Minimum ply height (Sylramic-iBN), mil**	**Maximum fiber fraction, percent**	**Average CMC UTS (8 plies), ksi**	**UTS per V_f*,[a] ksi**
20	10.0	38	60	316
16	8.4	37	62	335
12	7.2	35	65	371

[a]Fiber volume fraction in stress direction, V_f*.

References

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